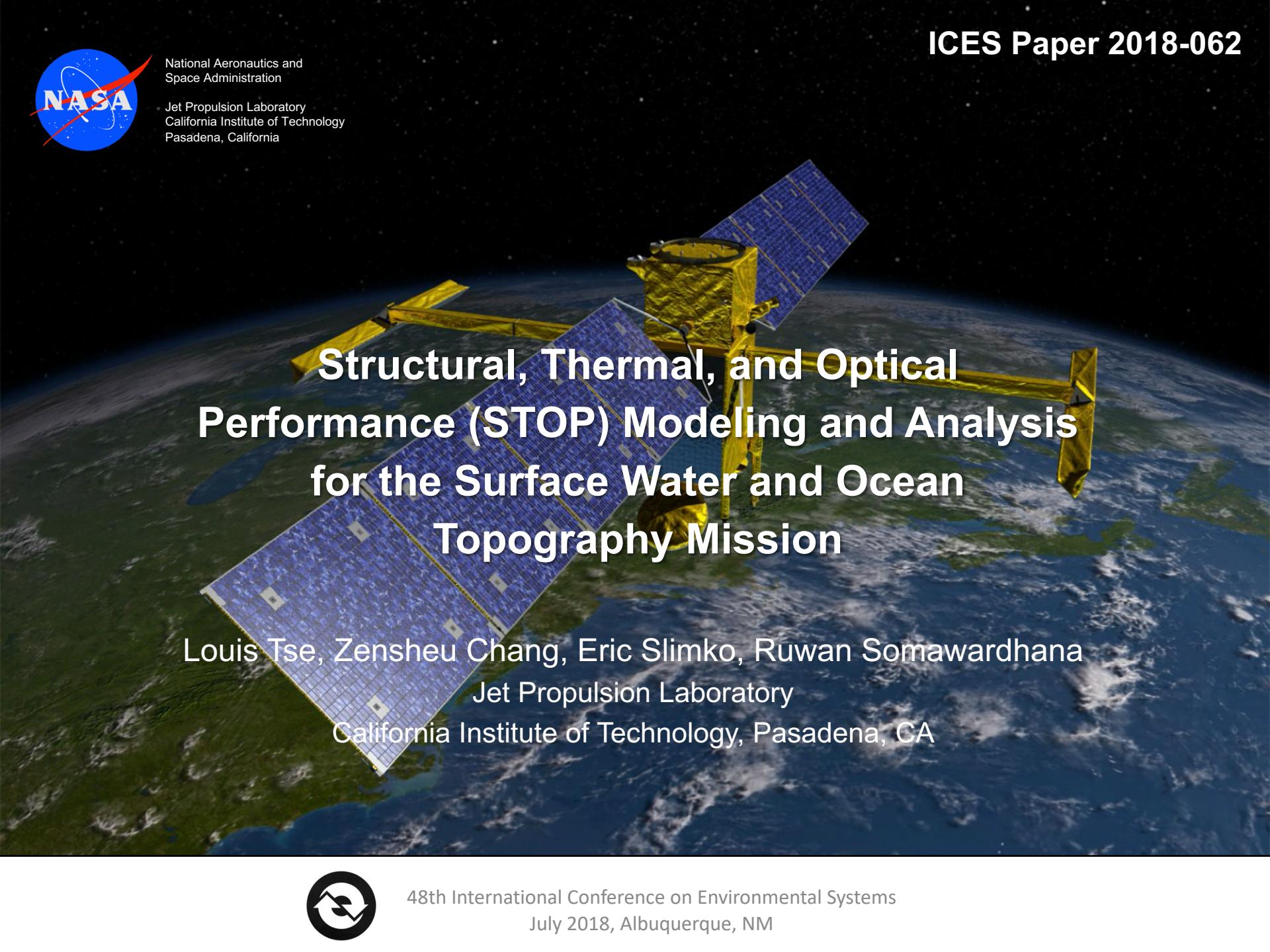




National Aeronautics and  
Space Administration

Jet Propulsion Laboratory  
California Institute of Technology  
Pasadena, California



# Structural, Thermal, and Optical Performance (STOP) Modeling and Analysis for the Surface Water and Ocean Topography Mission

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Jet Propulsion Laboratory  
California Institute of Technology, Pasadena, CA



48th International Conference on Environmental Systems  
July 2018, Albuquerque, NM

# Outline

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Background

KaRIn Instrument Performance Metrics

STOP Model Design & Analysis

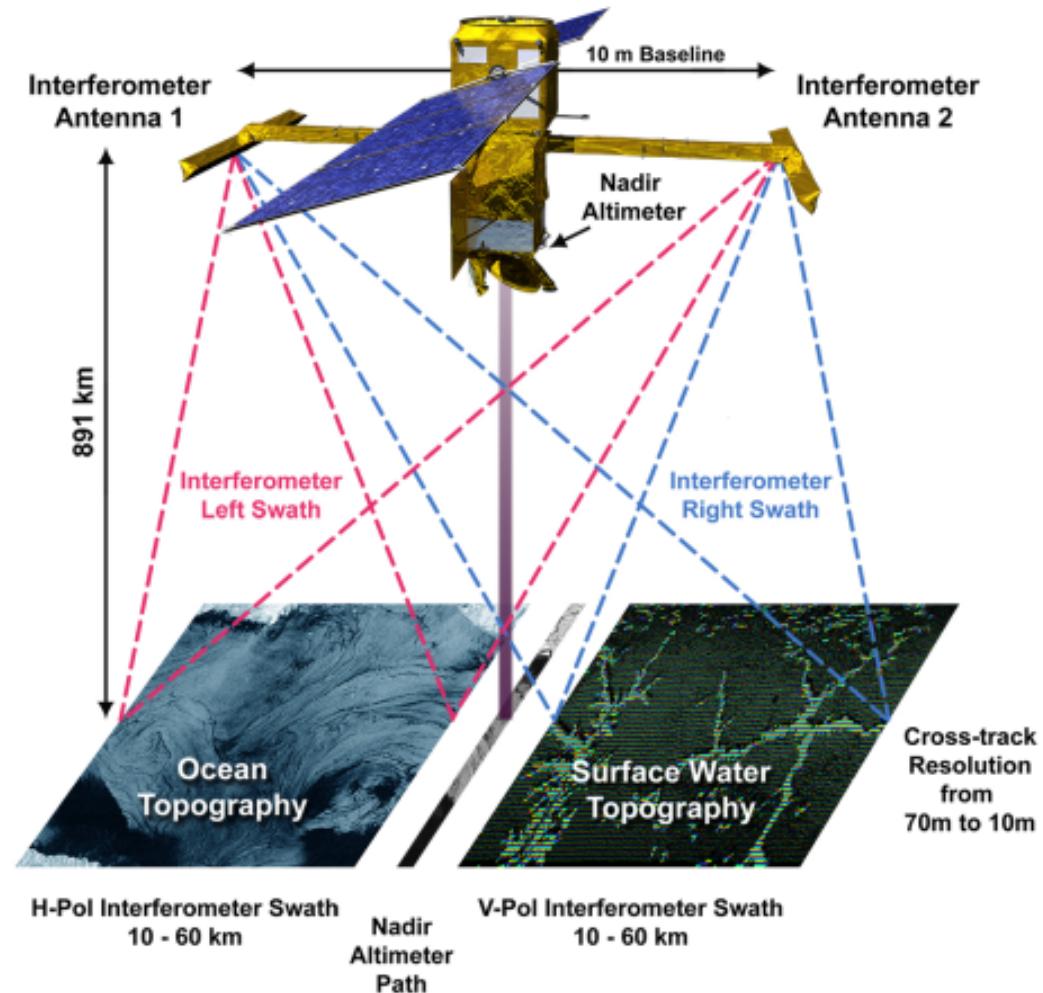
Lessons Learned

Conclusion

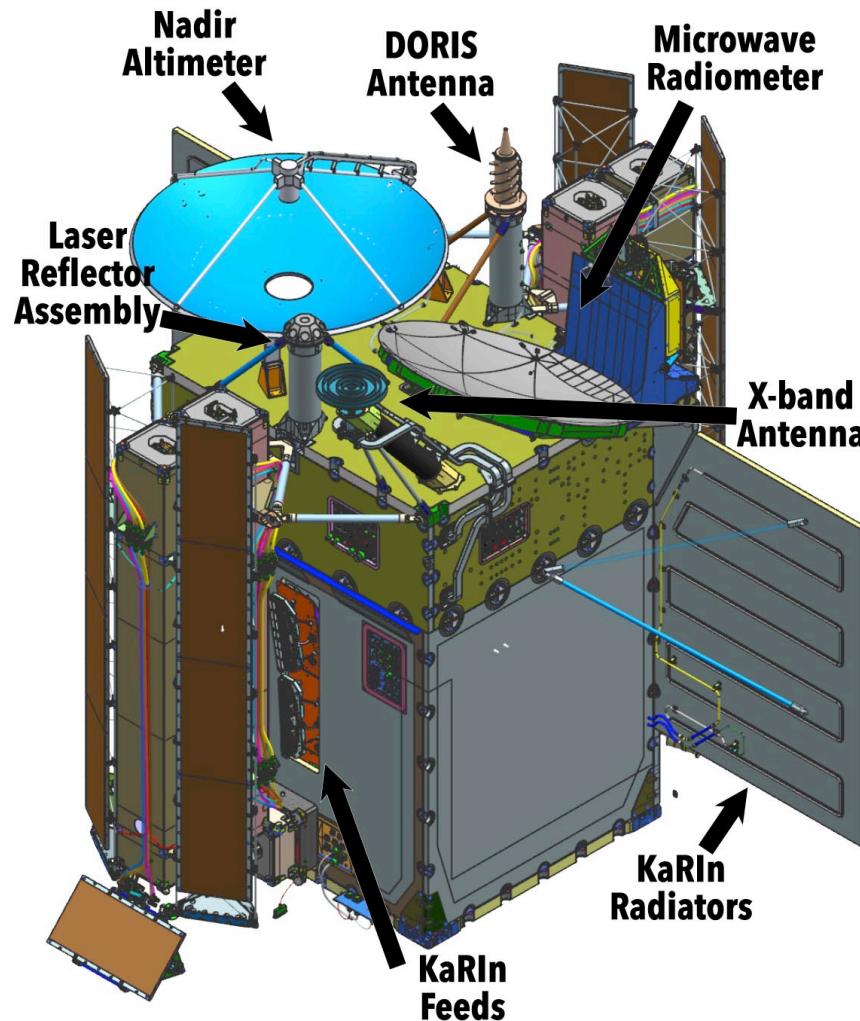


# Background

- SWOT will establish global survey of Earth's surface water
- Science objective: survey at least 90% of the globe, studying Earth's lakes, rivers, reservoirs and oceans
- Aims to improve ocean circulation and climate models, and aid in global freshwater management
- Ka- band Radar Interferometer (KaRIn) is primary instrument to achieve science objectives



# SWOT Payload (Stowed)



# Thermal Performance Requirements

## Thermal gradient requirement

1. Opto-mechanical stability of KaRIn RF chain to reduce signal noise
2. Optical stability governs distortion limits to structural design
3. Deformation limits define temperature gradients to thermal design

## Thermal stability requirement

- Temporal stability requirement of < 50 mK/min
- Fidelity of ocean topography measurement drives defined thermal stability requirements over different timescales
- Measurements at wavelengths shorter than 1,000 km corresponds to a time window of 2.6 minutes during nominal science orbit
- Land passes during science orbit extends to spatial scales longer than 12,500 km corresponds to a 31.6 minute time window



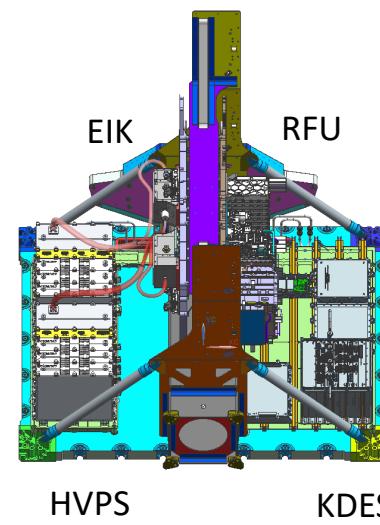
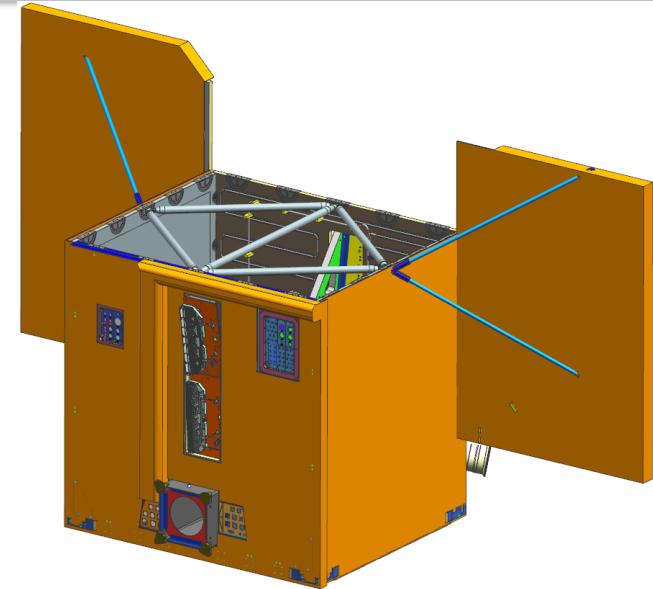
# KaRIn Thermal Pallet Design

## Design needs

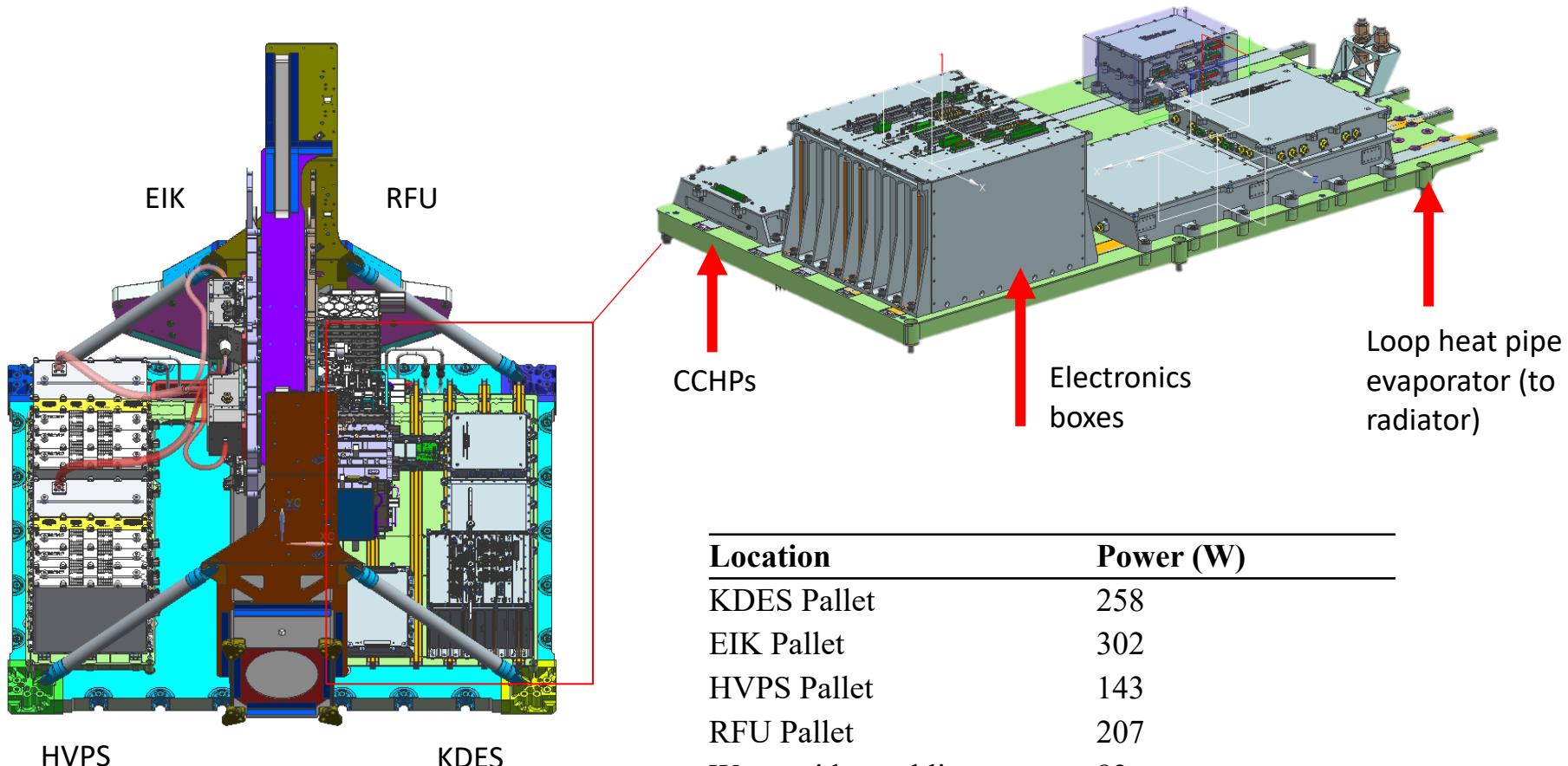
- Acute space constraints
- Dissipation greater than 1 kW
- Limited survival power

## Thermal design

- Four zones, each utilizing a thermal pallet with embedded constant conductance heat pipes (CCHPs)
- One loop heat pipe (LHP) with variable conductance to radiators



# KaRIn Thermal Pallet

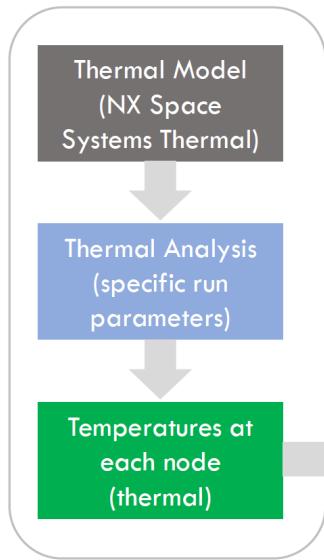


Location	Power (W)
KDES Pallet	258
EIK Pallet	302
HVPS Pallet	143
RFU Pallet	207
Waveguides, cabling	82
Feeds	14
Total	1006

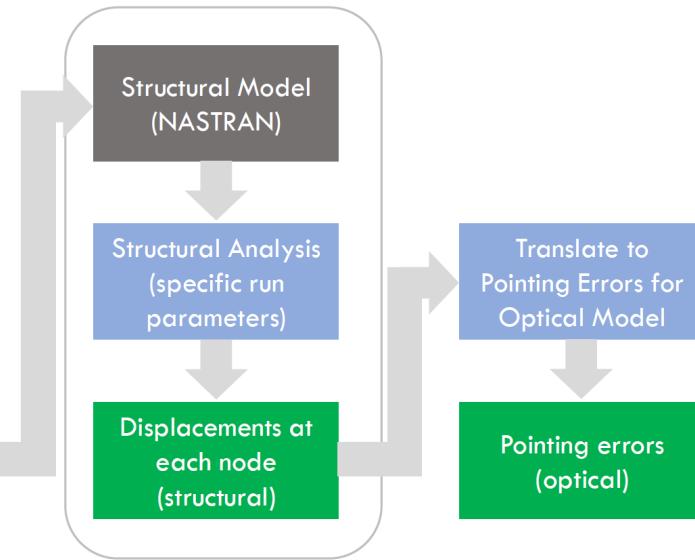


# STOP Design & Analysis Flow

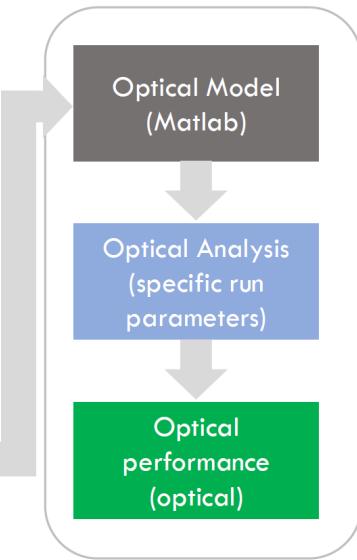
## Thermal



## Structural



## Optical



## Legend

Model

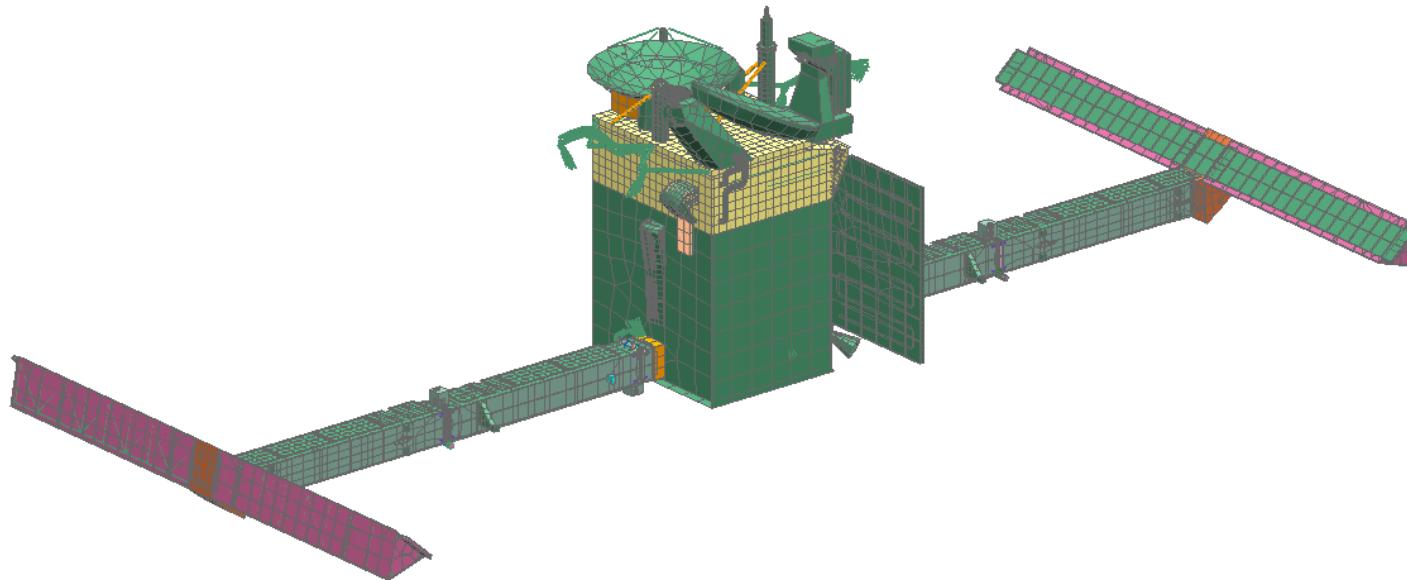
Process

Result



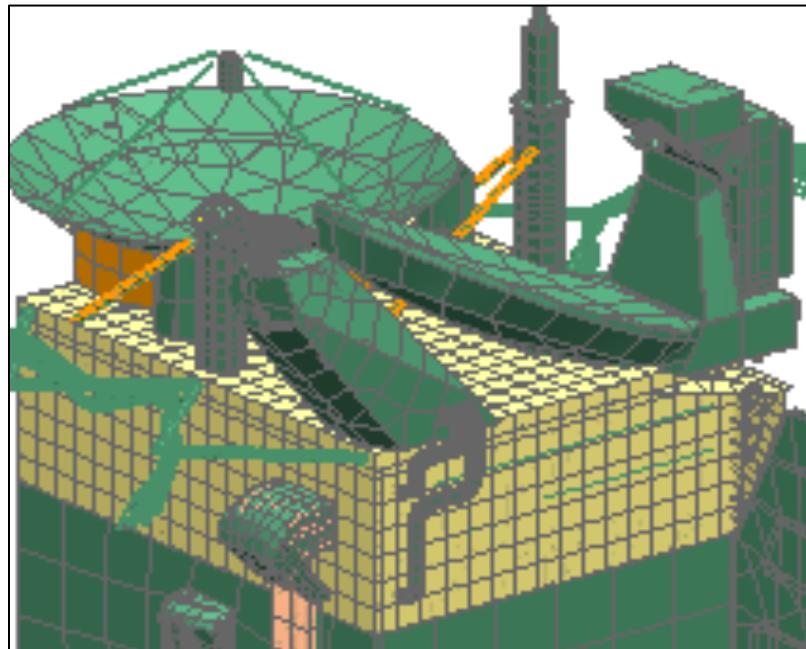
# Thermal Model Overview

- Thermal model generated in NX Space Systems Thermal:
  - Total elements: 53060 elements
  - Close linkage with actual CAD geometry
  - Mapping features to NASTRAN (for STOP analysis)
- Radiative conductors calculation via HEMICUBE

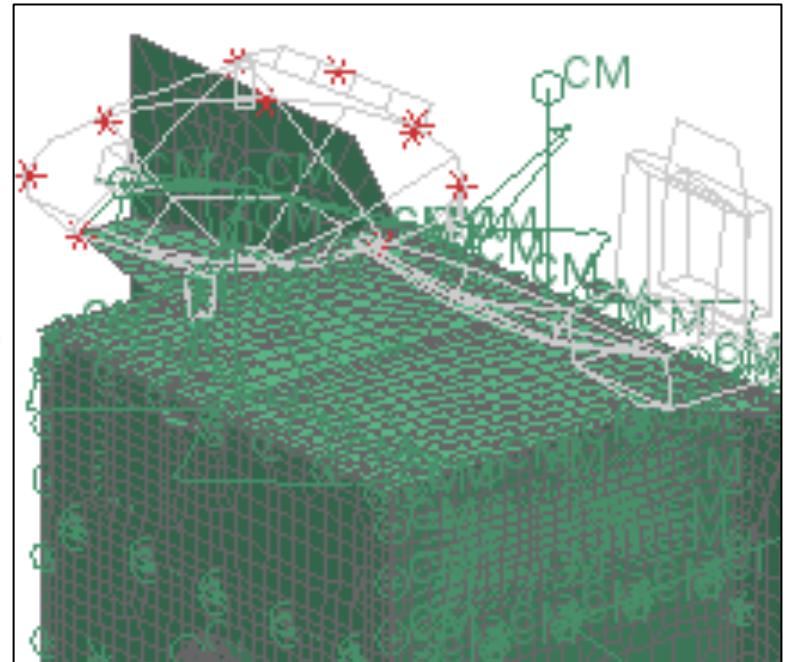


# Model Differences

**Thermal Model**



**Structural Model**

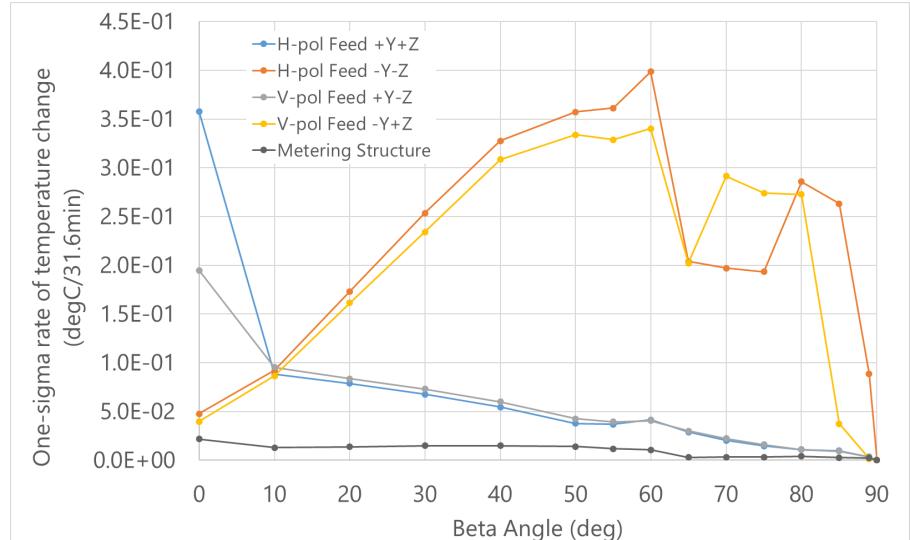
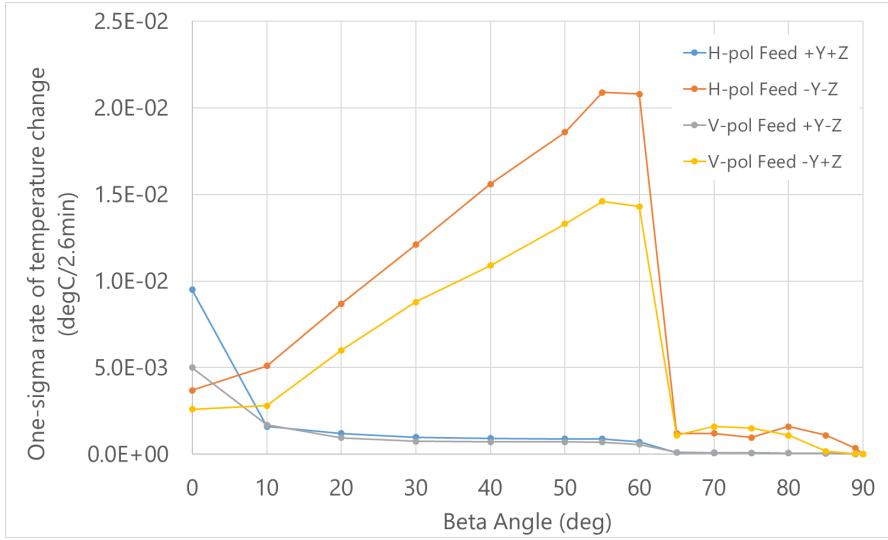


Parts integral to load path often simplified as ‘conductors’ in thermal model, and antennae and MLI are not meshed in structural model.



# Bounding Case for Thermal Stability

- Parametric study shows beta angle = 55° for largest thermal instability
- Maximizes fluctuation in lighting environment; highest solar flux with longest time in eclipse



# Thermal Stability Results

- All components meet thermal stability requirements, except for -Y Feeds
- Feeds: path forward is to calibrate using PRT measurement to reduce signal noise

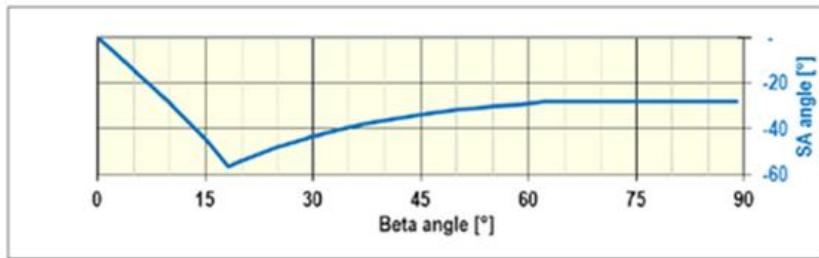
Component	Thermal Stability (°C/2.6min)	Requirement	Thermal Stability (°C/31.6min)	Requirement
H-pol Feed +Y+Z	9.01E-04	3.00E-02	3.74E-02	2.30E-01
H-pol Feed -Y-Z	2.07E-02	3.00E-02	<b>3.82E-01</b>	<b>2.30E-01</b>
V-pol Feed +Y-Z	7.12E-04	3.00E-02	3.86E-02	2.30E-01
V-pol Feed -Y+Z	1.44E-02	3.00E-02	<b>3.44E-01</b>	<b>2.30E-01</b>
H-pol Feed Bipod +Y+Z	1.62E-04	5.40E-01	1.58E-02	4.56E+00
H-pol Feed Bipod -Y-Z	2.00E-03	5.40E-01	1.75E-01	4.56E+00
V-pol Feed Bipod +Y-Z	1.42E-04	5.40E-01	1.66E-02	4.56E+00
V-pol Feed Bipod -Y+Z	1.90E-03	5.40E-01	1.85E-01	4.56E+00
Metering Structure	1.96E-04	1.40E-01	1.42E-02	1.14E+00
Boom +Y	1.64E-04	6.00E-02	4.17E-02	4.90E-01
Boom -Y	1.10E-03	6.00E-02	7.51E-02	4.90E-01
IRA Truss +Y	7.00E-03	2.20E-01	8.35E-01	1.82E+00
IRA Truss -Y	4.90E-03	2.20E-01	2.75E-01	1.82E+00
Reflector Panels +Y	1.13E-01	7.30E-01	4.33E+00	6.11E+00
Reflector Panels -Y	1.23E-02	7.30E-01	5.19E-01	6.11E+00



# Sensitivity Studies

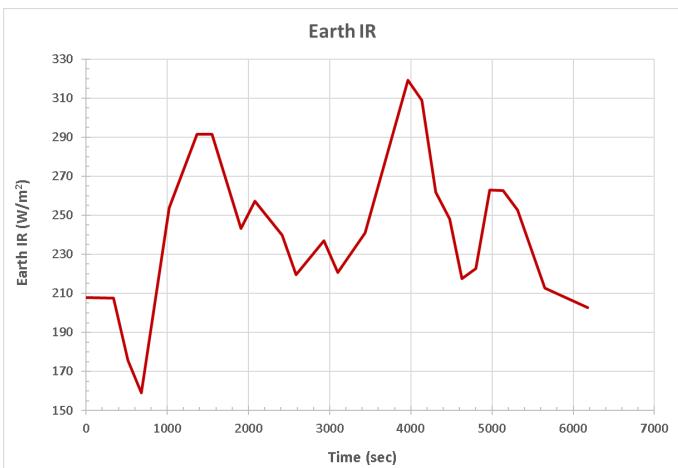
## 1. Solar array position changes during orbit

- Baseline: solar arrays fixed 0°
- Based on CNES data (largest rotation 56°)



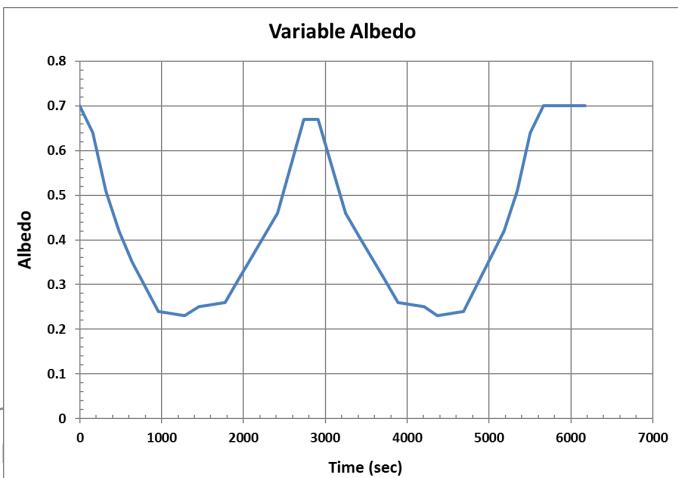
## 2. Variable albedo and Earth IR has high-frequency oscillations

- Baseline: constant EIR = 263 W/m<sup>2</sup>, albedo = 0.35
- Largest EIR change = 130 W/m<sup>2</sup> over 500 s, and albedo change = 0.4 (from ERBS)



## 3. Specular surfaces causes more focused reflected incident energy

- Baseline: no specular surfaces
- Solar arrays and S/C 100% specular



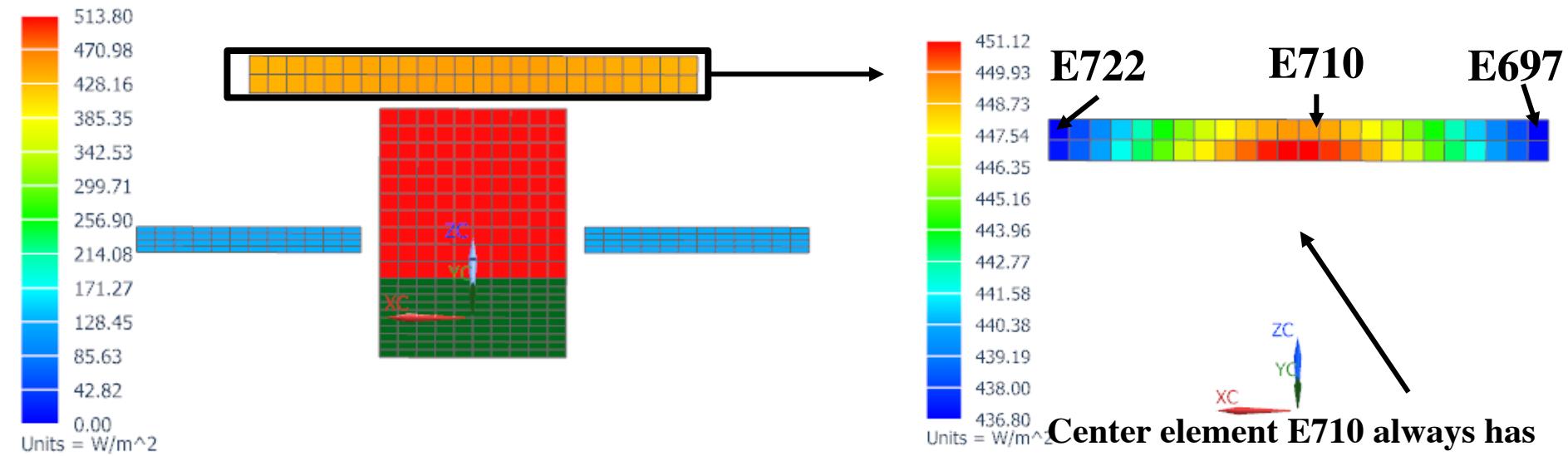
# Specularity Sensitivity Results

- While few areas (IRA Truss) show > 3x from baseline, significant margin against requirement remains (small numbers lend to large factor changes)

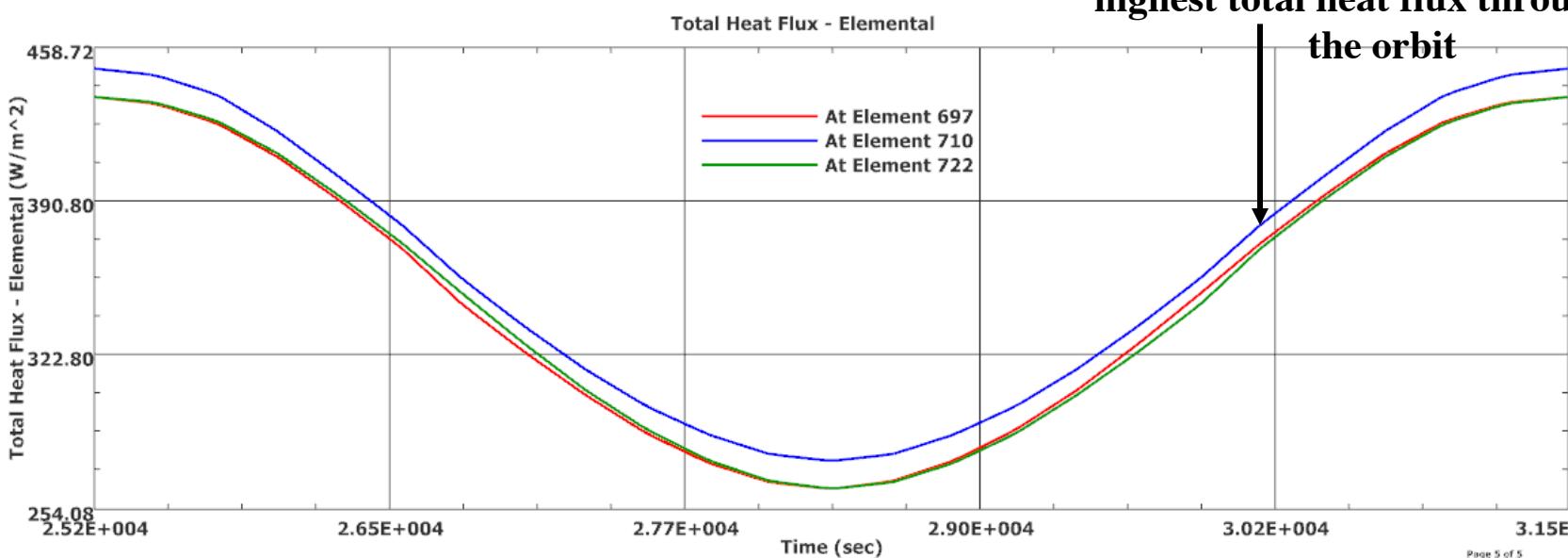
Component	Baseline Max 1- $\sigma$ 2.6min	Full Specular Max 1- $\sigma$ 2.6min	Delta (%)	REQ	Baseline Max 1- $\sigma$ 31.6min	Full Specular Max 1- $\sigma$ 31.6min	Delta (%)	REQ
H-pol Feed +Y+Z	9.01E-04	8.16E-04	-9%	3.00E-02	3.74E-02	4.23E-02	13%	2.30E-01
H-pol Feed -Y-Z	2.07E-02	2.05E-02	-1%	3.00E-02	3.82E-01	4.00E-01	5%	2.30E-01
V-pol Feed +Y-Z	7.12E-04	6.63E-04	-7%	3.00E-02	3.86E-02	4.23E-02	10%	2.30E-01
V-pol Feed -Y+Z	1.44E-02	1.40E-02	-3%	3.00E-02	3.44E-01	3.56E-01	3%	2.30E-01
H-pol Feed Bipod +Y+Z	1.62E-04	1.53E-04	-6%	5.40E-01	1.58E-02	1.80E-02	14%	4.56E+00
H-pol Feed Bipod -Y-Z	2.00E-03	1.90E-03	-5%	5.40E-01	1.75E-01	1.75E-01	0%	4.56E+00
V-pol Feed Bipod +Y-Z	1.42E-04	1.34E-04	-6%	5.40E-01	1.66E-02	1.75E-02	5%	4.56E+00
V-pol Feed Bipod -Y+Z	1.90E-03	1.80E-03	-5%	5.40E-01	1.85E-01	1.69E-01	-9%	4.56E+00
Metering Structure	1.96E-04	2.65E-04	35%	1.40E-01	1.42E-02	1.31E-02	-8%	1.14E+00
+Y Boom Inboard	1.64E-04	2.19E-04	34%	6.00E-02	4.17E-02	3.91E-02	-6%	4.90E-01
-Y Boom Inboard	1.10E-03	1.40E-03	27%	6.00E-02	7.51E-02	7.97E-02	6%	4.90E-01
IRA Truss +Y+X	7.00E-03	1.92E-02	174%	2.20E-01	8.35E-01	1.30E+00	56%	1.82E+00
IRA Truss +Y-X	4.50E-03	1.96E-02	336%	2.20E-01	1.15E+00	1.51E+00	31%	1.82E+00
IRA Truss -Y+X	4.90E-03	7.50E-03	53%	2.20E-01	2.75E-01	2.67E-01	-3%	1.82E+00
IRA Truss -Y-X	4.00E-03	7.60E-03	90%	2.20E-01	2.91E-01	2.87E-01	-1%	1.82E+00
Reflector Panels +Y	1.13E-01	1.78E-01	58%	7.30E-01	4.33E+00	5.78E+00	33%	6.11E+00
Reflector Panels -Y	1.23E-02	1.62E-02	32%	7.30E-01	5.19E-01	4.95E-01	-5%	6.11E+00



# Baseline Specularity Run: Reflectarray Total Heat Flux Contour at End of Orbit

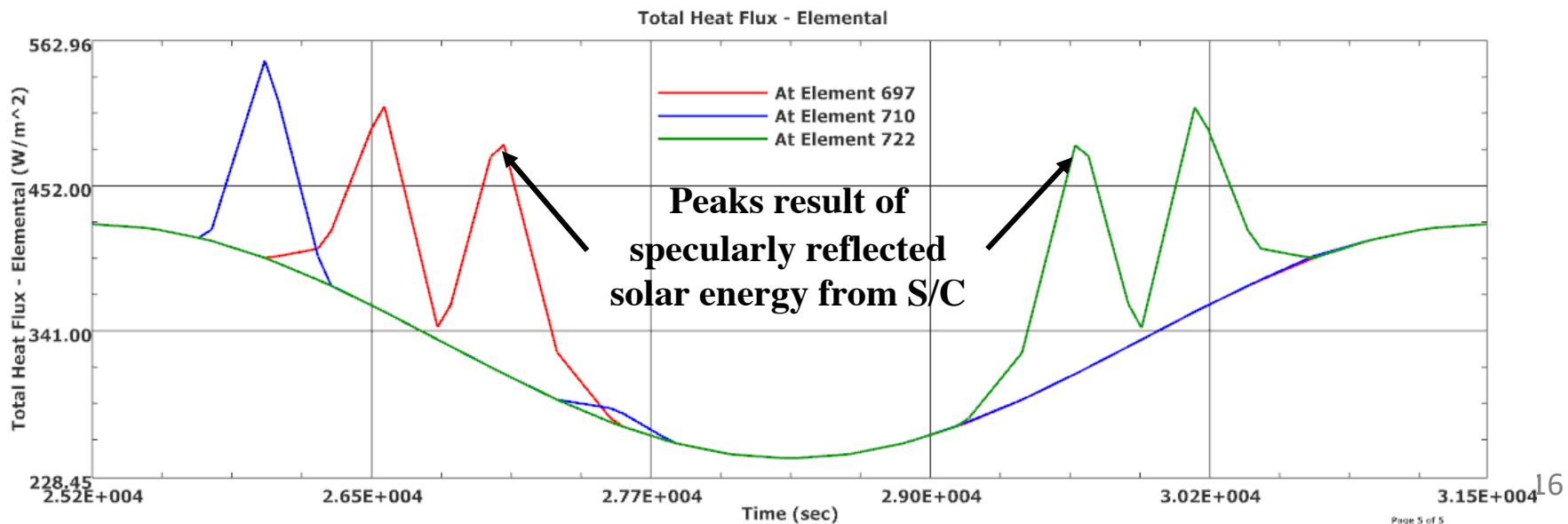
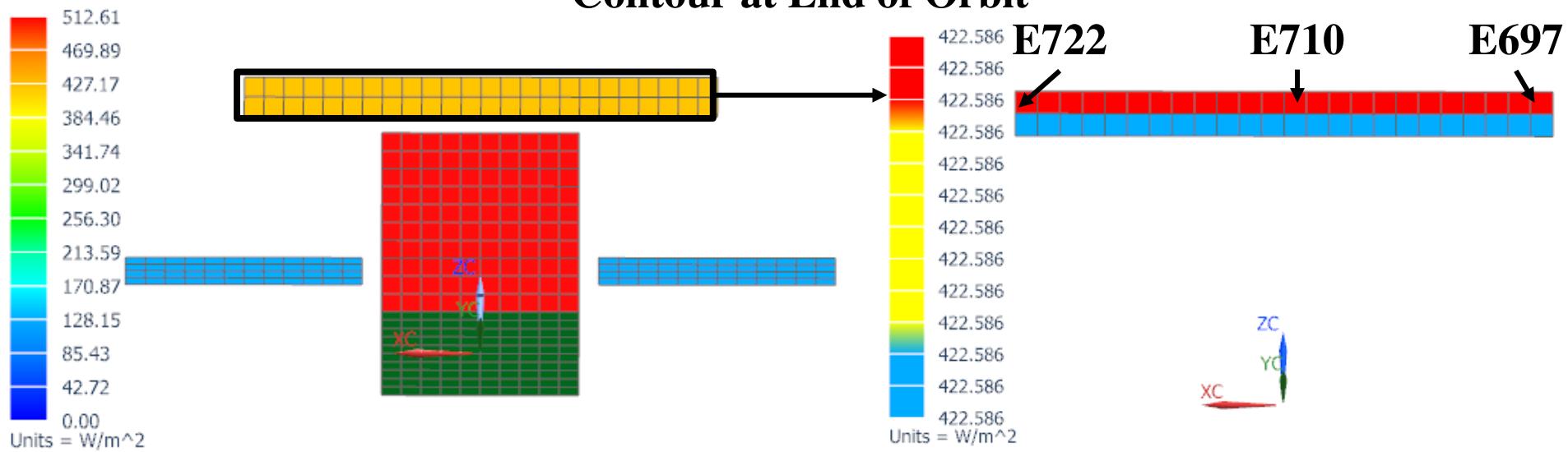


**Center element E710 always has highest total heat flux throughout the orbit**

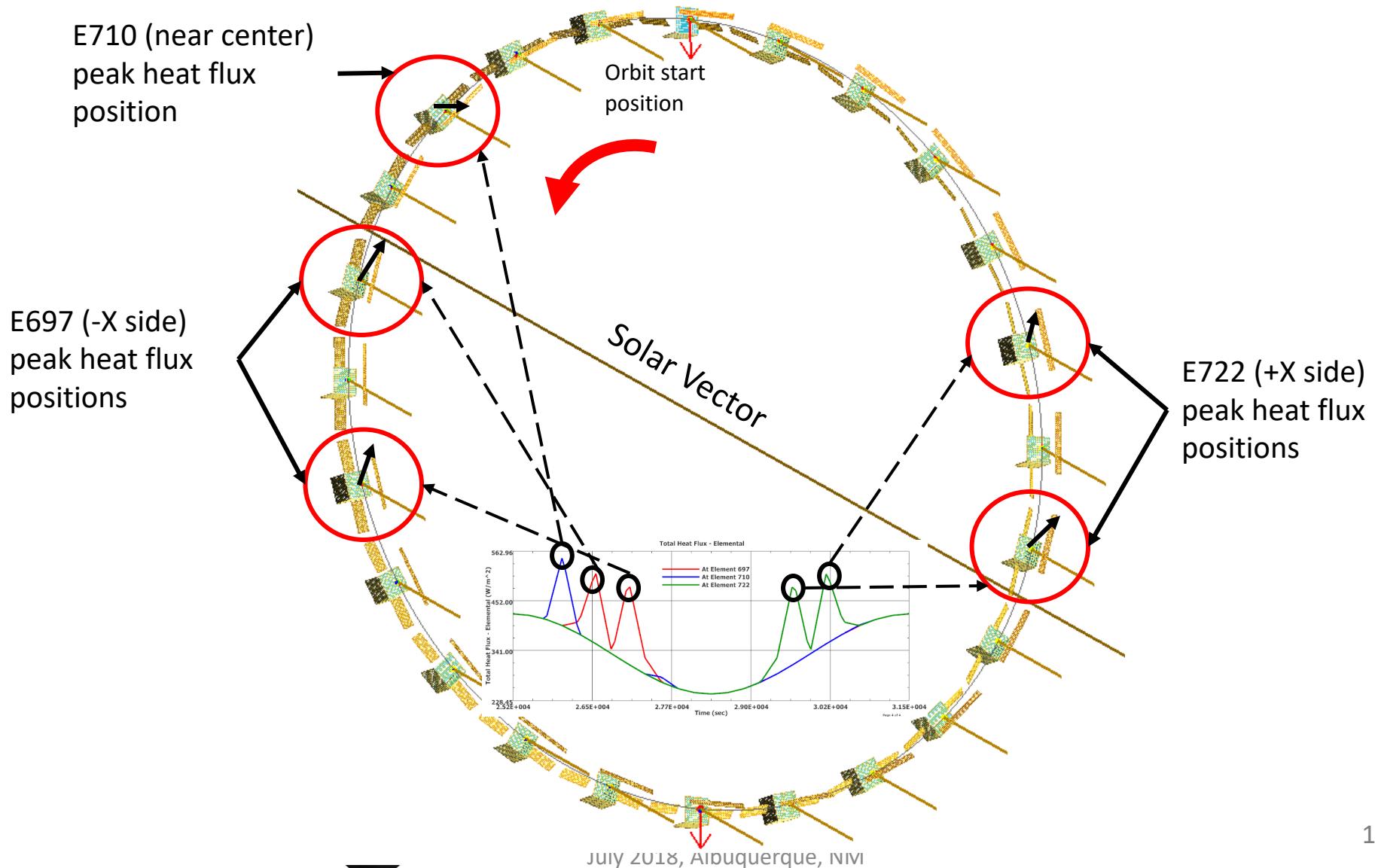


# Sensitivity Specularity Run: Reflectarray Total Heat Flux

Contour at End of Orbit



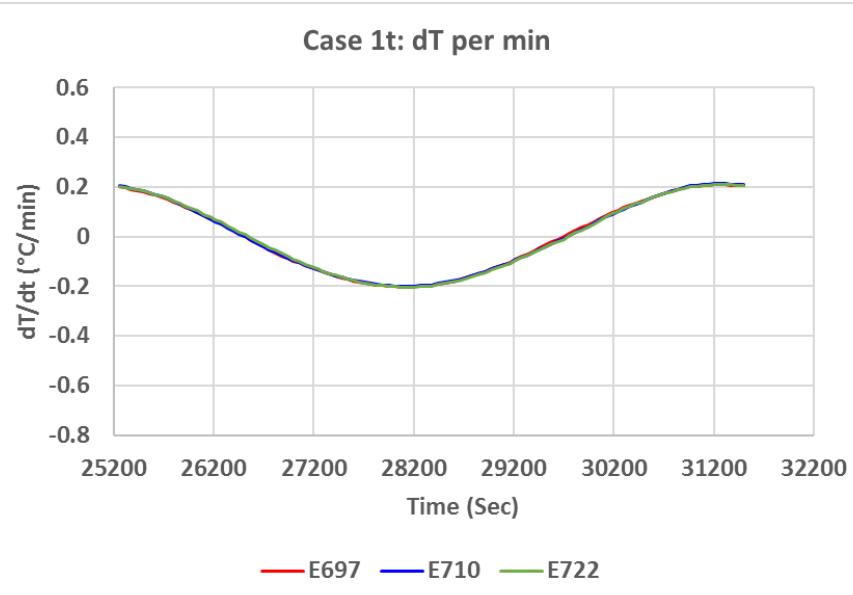
# Orbital Positions Correspond to Peak Heat Flux



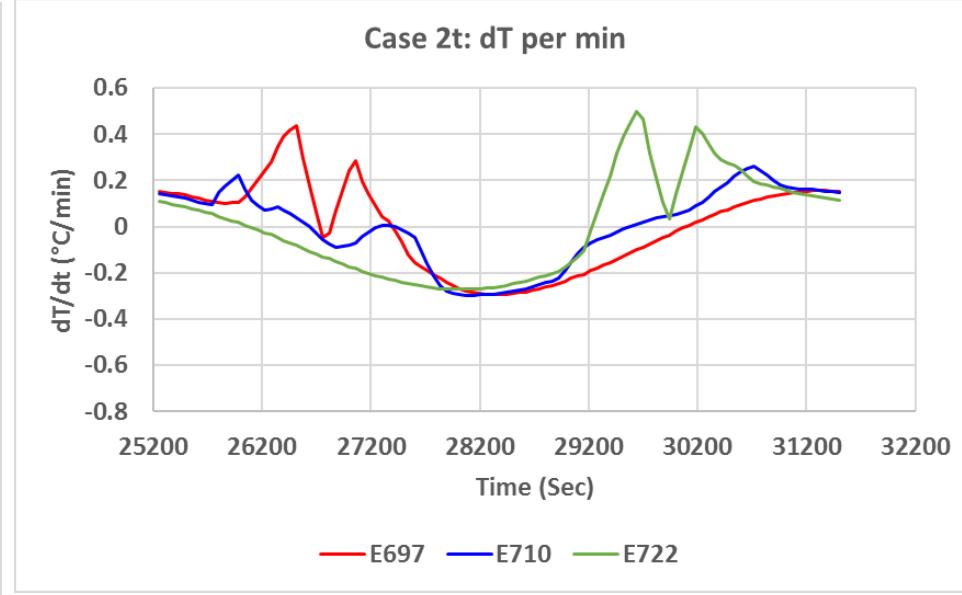
# Effect of Specularity on Thermal Stability

- Specularity has large impact on reflectarray's thermal stability
  - Temperature change per minute plotted for three elements on reflectarray for baseline and sensitivity runs
  - Peaks are due to increased solar energy specularly reflected
  - Maximum temperature change per minute in sensitivity run is **2.5 times higher** than that in baseline.

Baseline (No Specularity)  
Max  $dT/dt = 0.2^\circ\text{C}/\text{min}$



Sensitivity (Specularity)  
Max  $dT/dt = 0.5^\circ\text{C}/\text{min}$



# Thermal Mapping in NX

- Default mapping process: nodes matched by proximity
- Structural nodes interpolate from nearest thermal nodes
- More precise mapping techniques: targeted mapping, exclusion
  - Requires manual definition of Mapping Zones

**Thermal Model**



Units = C

**Structural Model**



Units = C

# Mapping errors in NX

## Mapping is time-consuming and error prone

- NX uses node proximity as the default mode to match nodes between the two models
- Using the nearest node method is often used for large system models, due to time constraints, though can lead to artificial thermal gradients

## Recommendation: Use *Targeted Mapping* functions, NXOpen

- Targeted Mapping in NX entails extensive manual mapping to limits specific thermal nodes that can be mapped to corresponding structural nodes
- Drawback is significant time to create these relational groups that correspond between two models
- NXOpen scripts can increase accuracy of model setup



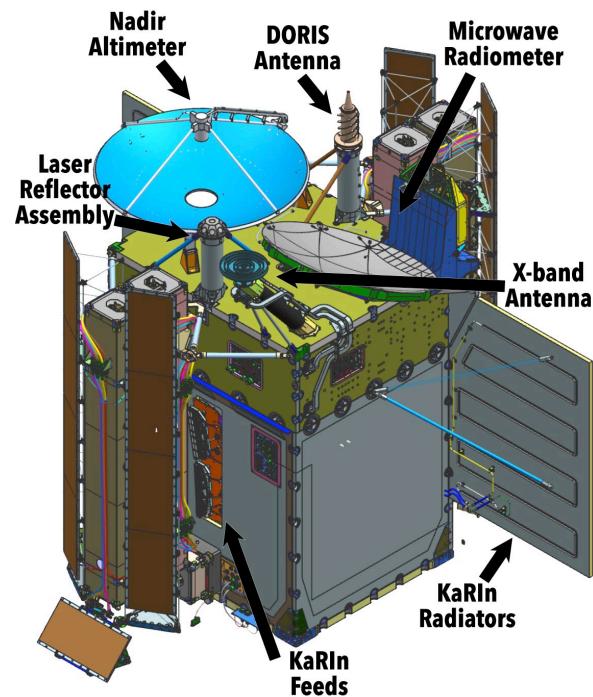
# Radk calculations in NX

## Radk calculation significant barrier to STOP design

- Computationally expensive
- Each model often requires disparate components to be high-fidelity, which can result in large models

## Recommendation: Define separate radiation enclosures in NX

- Define separate radiation enclosures to lessen number of radks
- More streamlined STOP process greatly enables STOP into design phase



Enclosure Case	Elements in sub-enclosures	Model Runtime
No sub-enclosure	-	34 hrs
KaRIn sub-enclosure	23823	26 hrs
KaRIn and Nadir sub-enclosure	32919	23 hrs



# Data and Software Management

## **Data and software management is a major bottleneck**

- Multi-disciplinary analysis necessitates different software packages
- Requires streamlined data exchange methods between different models
- STOP data has to be converted into a suitable format for analysis for each discipline. Data manipulation is often conducted by one-use codes or by hand

## **Recommendation: Utilize integrated analysis tool package**

- Develop automated data management tool for the specific set of analysis tools used, to establish consistent inputs and outputs
- Develop automated software management tool, which would not only improve analysis flow, but design flow as well
- OptiOpt (C&R) and IMPipeline (WFIRST) are integrated analysis tool packages



# Prognostic STOP Tools

## NXOpen Script for NX-NASTRAN Mapping

- NXOpen is collection of APIs that allow custom applications to be built using well-known programming languages
- Script was built to identify problematic mapping thermal-structural element matches and other common thermal mapping errors

## MATLAB Postprocessing Script for NX SimCenter

- Script was built to reduce postprocessing time using native NX postprocessor
- 10 hours of native NX postprocessor → 1 hour of MATLAB script

Goal is to release as beta versions for open-source use.



# Conclusion

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- STOP analysis results for the SWOT mission were presented
- KaRIn performance requirements have been met
- Lessons learned for more efficient STOP design and analysis are detailed
- Prognostic tools to be open-source to enable STOP in design process



# Acknowledgements

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- Ruwan Somawardhana, Eug-Yun Kwack, Howard Tseng (JPL)
- Chris Pye, Jean Frederic Ruel (MAYA Heat Transfer Technologies)
- The work described was performed at the Jet Propulsion Laboratory of the California Institute of Technology, under contract with the National Aeronautics and Space Administration
- © 2018 California Institute of Technology. Government sponsorship acknowledged.



# Thank You

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- Questions?
- Contact: [louis.a.tse@jpl.nasa.gov](mailto:louis.a.tse@jpl.nasa.gov)



# Backup

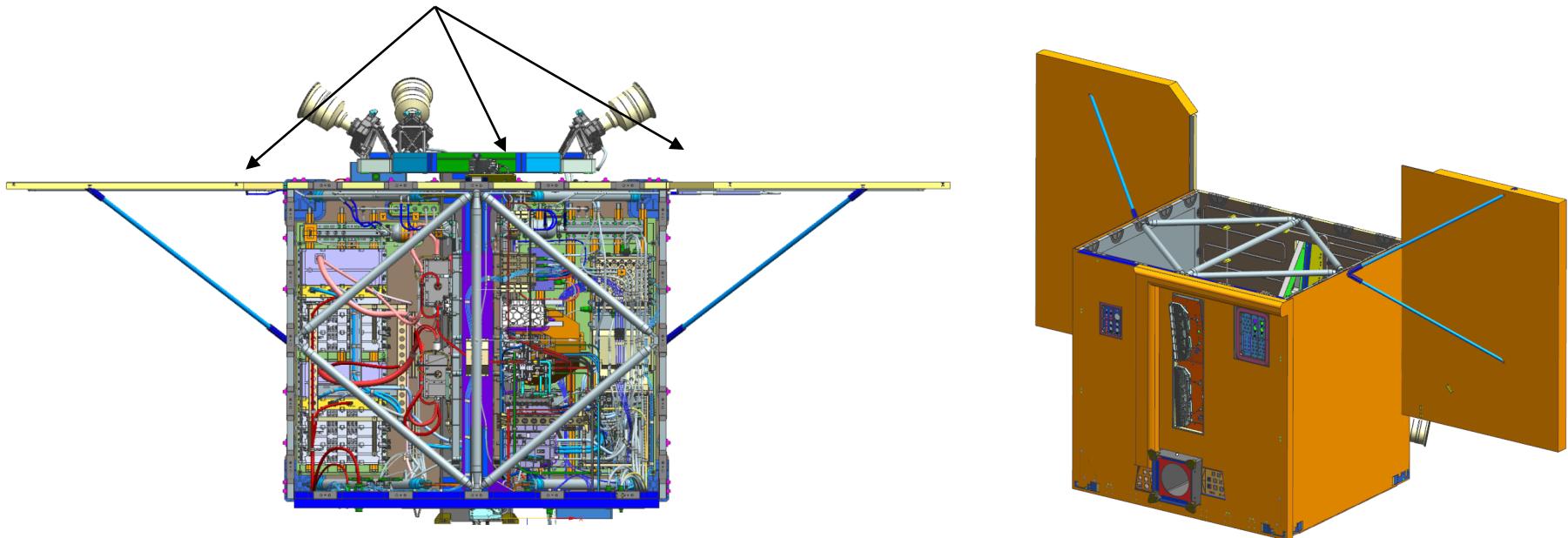
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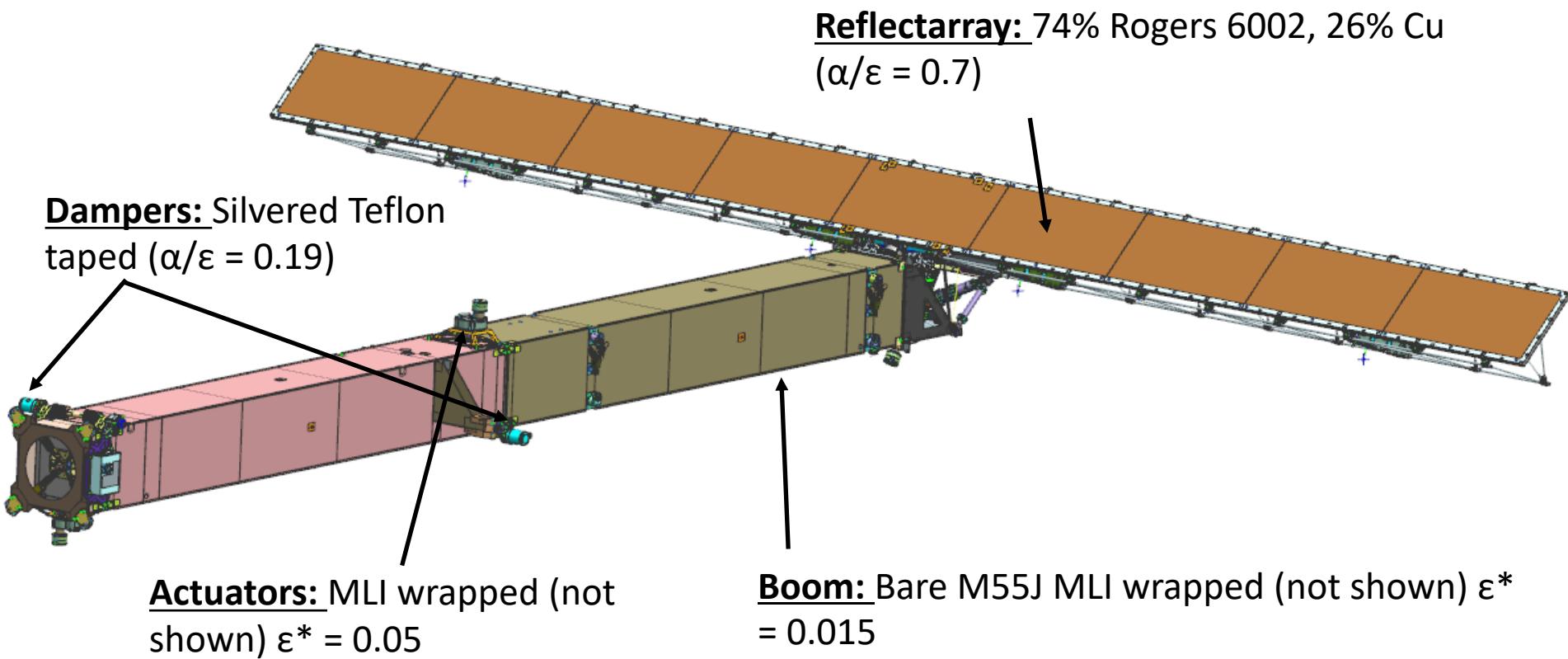
48th International Conference on Environmental Systems  
July 2018, Albuquerque, NM

# KaRIn Module

**KaRIn Radiators:** white paint radiator ( $\alpha/\varepsilon = 0.34$ ) on +Y panel to maintain stability



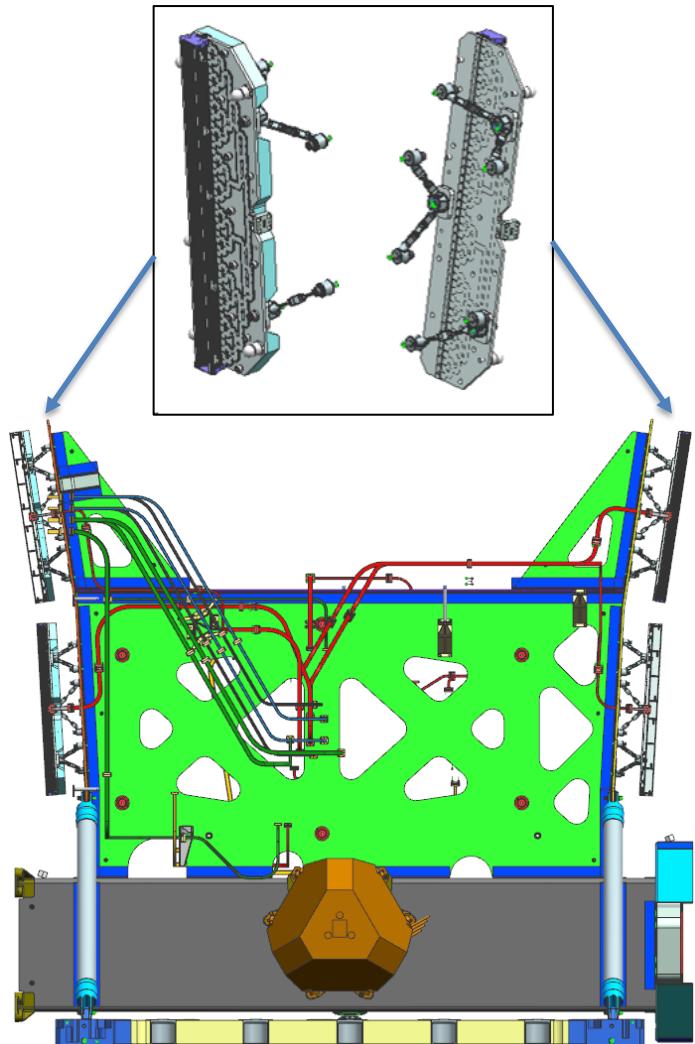
# Deployable Antenna Assembly (DAA)



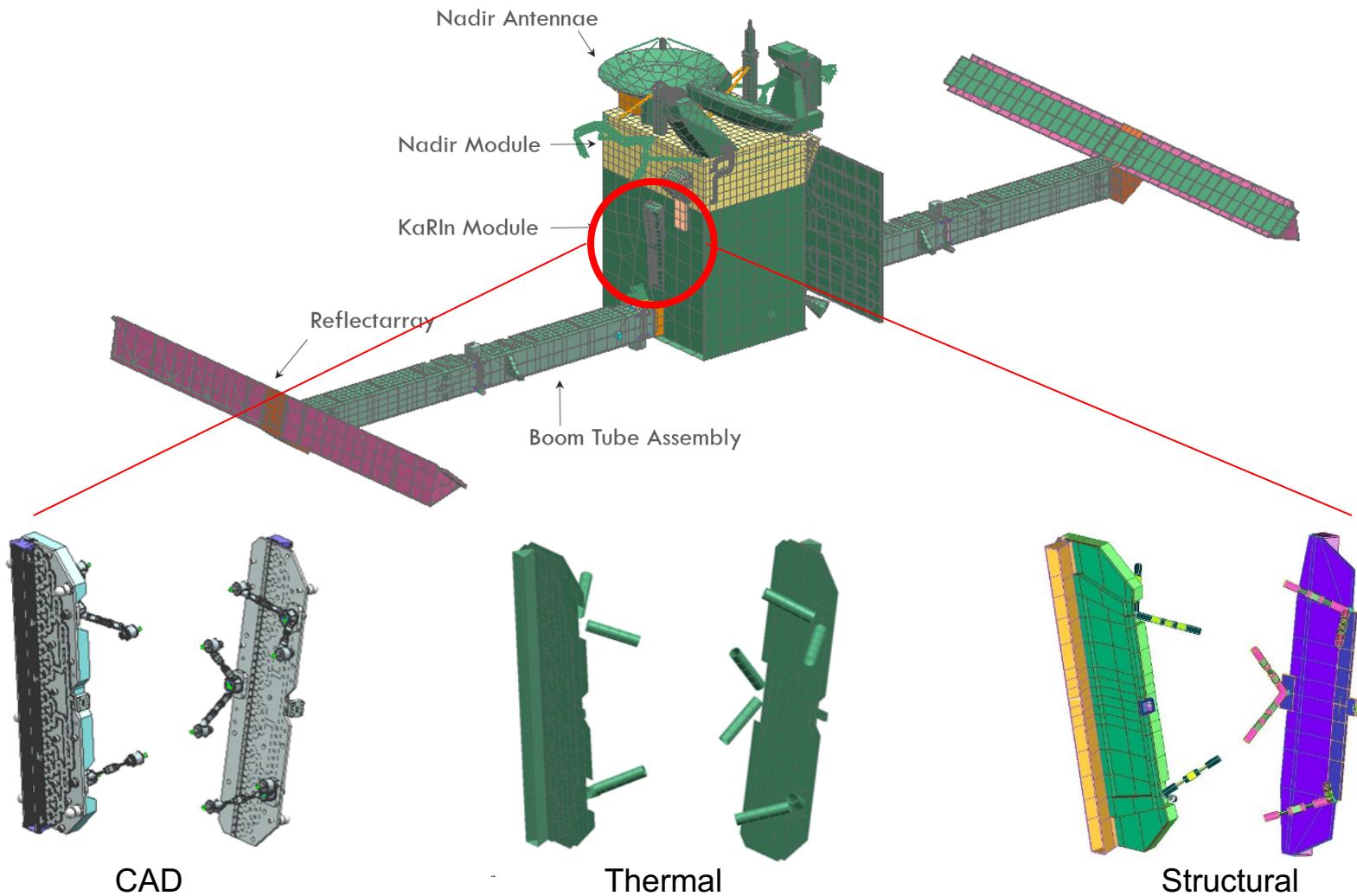
# Feeds

## Feeds:

- Aperture has effective emissivity based on: 50% blackbody grooves, 50% Chemfilm ( $\alpha/\epsilon = 1.27$ )
- Remainder of feed blanketed ( $\epsilon^* = 0.075$ )
- 1.5kg thermal mass on -Y side per feed to maintain thermal stability

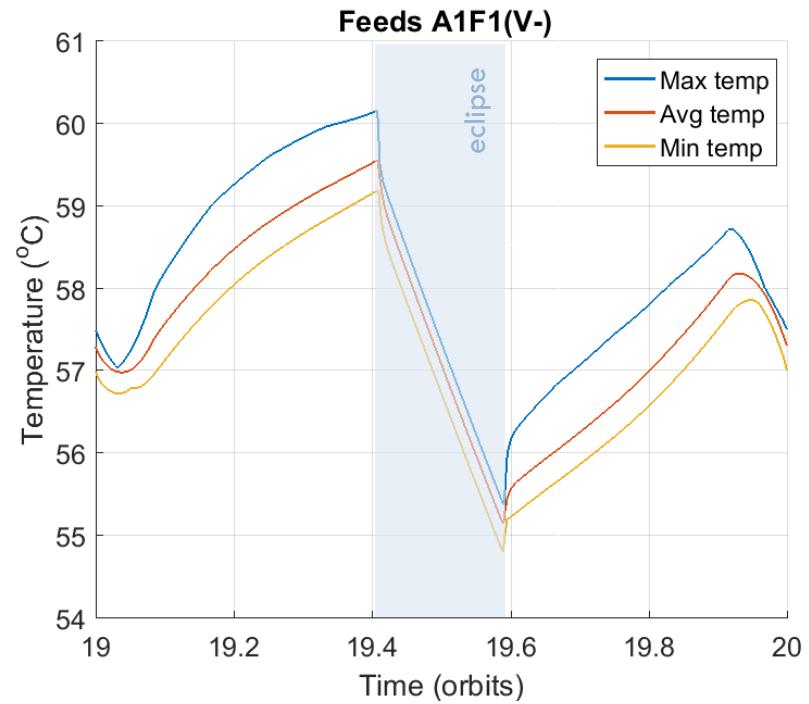
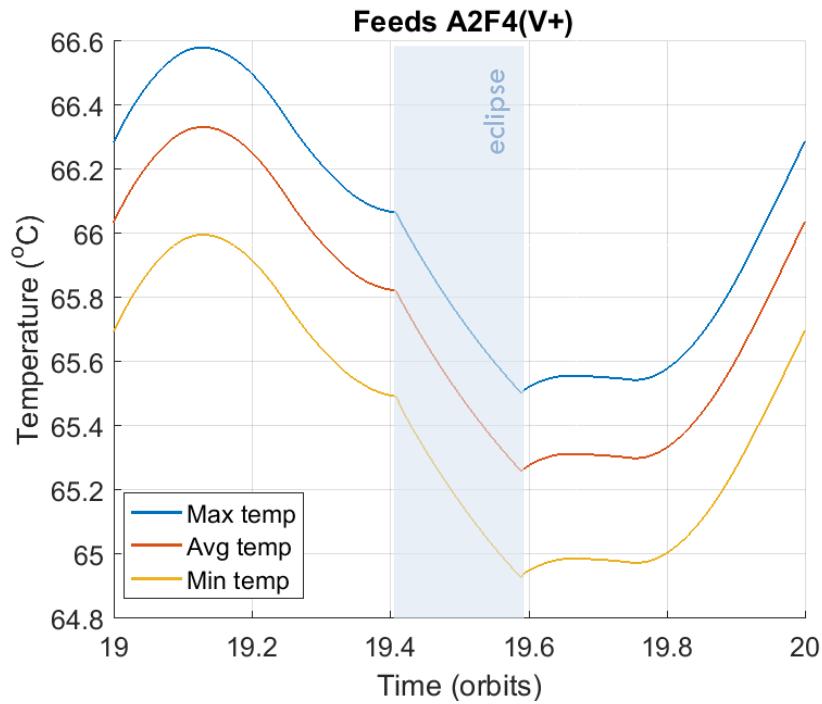


# Mesh Comparison

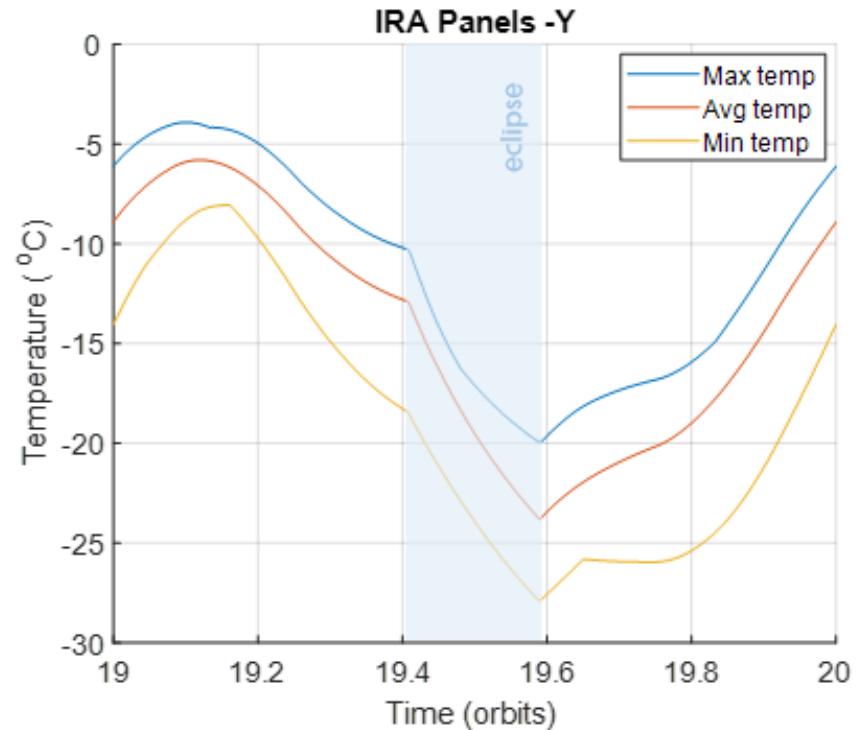
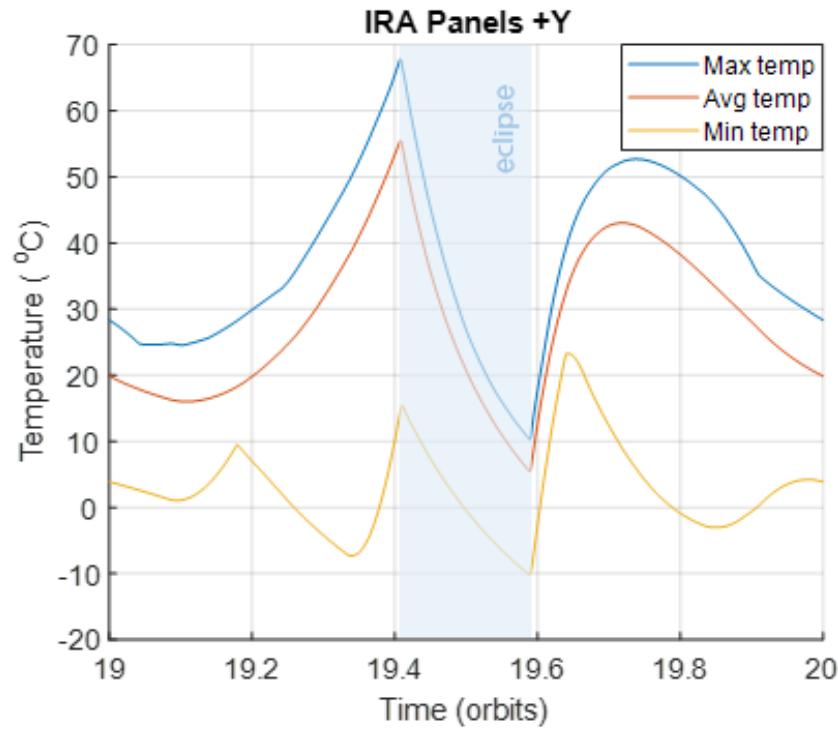


For the feeds, thermal model has 10x elements than structural model.

# Feeds



# Reflectarrays



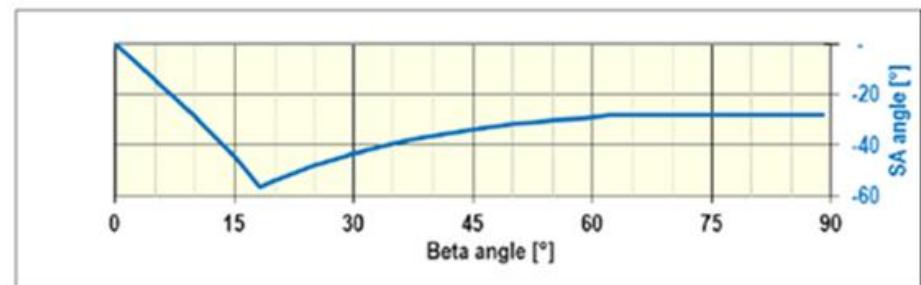
# Solar Array Positions

## Objective:

- Solar array rotation impact to temperature stability
  - Solar array will change positions during orbit based on CNES data provided

## Assumptions:

- WCH environments and instrument power
- Beta00:
  - SA angle = 0°
- Beta18:
  - Baseline angle = 0°
  - SA angle = -56°
- Beta65:
  - Baseline angle = 0°
  - SA angle = -30°
- Beta90:
  - Baseline angle = 0°
  - SA angle = -30°



# Temperature Stability – 2.6min

2.6min	BETA00	BETA18				BETA55				BETA65				BETA90				REQ
	BASEL1 NE	BASEL1 NE	SA -56	Delta	% Change	BASEL1 NE	SA -30	Delta	% Change	BASEL1 NE	SA -30	Delta	% Change	BASEL1 NE	SA -30	Delta	% Change	
H-pol Feed +Y+Z	9.5E-03	1.6E-03	1.3E-03	-3.0E-04	-19%	8.9E-04	7.39E-04	-1.5E-04	-17%	9.1E-05	5.4E-05	-3.7E-05	-41%	1.8E-06	2.0E-06	2.2E-07	12%	3.00E-02
H-pol Feed -Y-Z	3.7E-03	1.0E-02	8.8E-03	-1.3E-03	-13%	2.1E-02	2.09E-02	0.0E+00	0%	1.2E-03	1.6E-03	4.0E-04	33%	2.5E-06	2.5E-06	1.6E-09	0%	3.00E-02
V-pol Feed +Y-Z	5.0E-03	1.3E-03	1.0E-03	-3.0E-04	-23%	7.0E-04	5.93E-04	-1.1E-04	-15%	1.1E-04	7.1E-05	-3.8E-05	-35%	2.1E-06	3.1E-06	1.0E-06	49%	3.00E-02
V-pol Feed -Y+Z	2.6E-03	6.3E-03	5.4E-03	-9.0E-04	-14%	1.5E-02	1.46E-02	0.0E+00	0%	1.1E-03	1.5E-03	4.0E-04	36%	2.5E-06	2.6E-06	1.4E-07	0%	3.00E-02
H-pol Feed Bipod +Y+Z	2.1E-03	3.4E-03	2.6E-04	-3.1E-03	-92%	1.5E-04	1.34E-04	-2.0E-05	-13%	4.2E-05	2.8E-05	-1.3E-05	-32%	2.3E-06	6.0E-04	6.0E-04	26364%	5.40E-01
H-pol Feed Bipod -Y-Z	4.4E-04	2.2E-03	8.3E-04	-1.4E-03	-62%	1.9E-03	1.90E-03	0.0E+00	0%	3.0E-04	3.9E-04	9.2E-05	31%	1.8E-06	1.3E-03	1.3E-03	71082%	5.40E-01
V-pol Feed Bipod +Y-Z	1.2E-03	3.3E-03	2.5E-04	-3.0E-03	-92%	1.3E-04	1.23E-04	-9.8E-06	-7%	4.7E-05	3.6E-05	-1.0E-05	-22%	2.5E-06	8.8E-04	8.7E-04	35664%	5.40E-01
V-pol Feed Bipod -Y+Z	8.9E-04	1.7E-03	9.9E-04	-7.1E-04	-42%	1.9E-03	1.90E-03	0.0E+00	0%	2.7E-04	3.9E-04	1.2E-04	46%	2.0E-06	2.3E-06	2.8E-07	14%	5.40E-01
Metering Structure	2.3E-04	1.4E-03	1.4E-04	-1.3E-03	-90%	1.9E-04	1.81E-04	-8.2E-06	-4%	9.4E-06	2.3E-05	1.4E-05	145%	3.1E-06	5.9E-04	5.8E-04	18753%	1.40E-01
+Y Boom Inboard	1.3E-03	1.5E-03	7.7E-04	-7.3E-04	-48%	1.9E-04	1.82E-04	-1.3E-05	-7%	1.2E-04	1.7E-04	4.6E-05	37%	8.2E-05	8.7E-05	4.5E-06	5%	6.00E-02
+Y Boom Outboard	1.0E-03	1.6E-03	9.6E-04	-6.4E-04	-40%	8.6E-04	5.13E-04	-3.4E-04	-40%	2.1E-04	2.5E-04	4.5E-05	22%	1.9E-04	1.8E-04	-6.8E-06	-4%	6.00E-02
-Y Boom Inboard	1.4E-03	1.6E-03	1.2E-03	-4.0E-04	-25%	1.1E-03	1.10E-03	0.0E+00	0%	8.6E-05	1.7E-04	8.1E-05	94%	3.1E-05	3.5E-05	4.0E-06	13%	6.00E-02
-Y Boom Outboard	1.0E-03	1.2E-03	9.7E-04	-2.3E-04	-20%	5.9E-04	5.80E-04	-1.0E-05	-2%	1.7E-04	2.0E-04	3.0E-05	18%	9.7E-05	9.8E-05	7.2E-07	1%	6.00E-02
IRA Truss +Y+X	2.9E-03	3.9E-03	3.3E-03	-6.0E-04	-15%	6.6E-03	6.60E-03	0.0E+00	0%	5.8E-03	5.0E-03	-8.0E-04	-14%	6.9E-06	6.1E-06	-8.6E-07	-12%	2.21E-01
IRA Truss +Y-X	3.0E-03	3.8E-03	3.2E-03	-6.0E-04	-16%	6.6E-03	6.30E-03	-3.0E-04	-5%	6.1E-03	5.6E-03	-5.0E-04	-8%	6.9E-06	6.1E-06	-8.8E-07	-13%	2.21E-01
IRA Truss -Y+X	3.0E-03	4.2E-03	3.5E-03	-7.0E-04	-17%	4.3E-03	4.30E-03	0.0E+00	0%	5.9E-04	5.1E-04	-8.1E-05	-14%	3.1E-06	1.6E-06	-1.5E-06	-47%	2.21E-01
IRA Truss -Y-X	2.9E-03	4.1E-03	3.5E-03	-6.0E-04	-15%	4.3E-03	4.30E-03	0.0E+00	0%	6.3E-04	5.8E-04	-4.8E-05	-8%	3.0E-06	1.6E-06	-1.4E-06	-46%	2.21E-01
Reflector Panels All	5.0E-02	5.9E-02	5.1E-02	-8.5E-03	-14%	7.0E-02	6.62E-02	-4.2E-03	-6%	4.3E-03	4.5E-03	2.0E-04	5%	6.5E-06	4.9E-06	-1.6E-06	-24%	7.30E-01

Some components have large % change but absolute stabilities are still within requirements with margins  
 All components meet the requirements



# Temperature Stability – 31.6min

31.6min	BETA00	BETA18				BETA55				BETA65				BETA90				REQ
	BASELI NE	BASELI NE	SA -56	Delta	% Change	BASELI NE	SA -30	Delta	% Change	BASELI NE	SA -30	Delta	% Change	BASELI NE	SA -30	Delta	% Change	
H-pol Feed +Y+Z	3.6E-01	5.9E-03	7.9E-02	7.3E-02	1237%	3.7E-02	3.18E-02	-5.0E-03	-14%	2.9E-02	1.2E-02	-1.7E-02	-58%	6.8E-05	2.2E-05	-4.6E-05	-68%	2.30E-01
H-pol Feed -Y-Z	4.7E-02	7.3E-02	1.7E-01	9.9E-02	135%	3.6E-01	3.61E-01	-4.0E-04	0%	2.0E-01	2.0E-01	-4.2E-03	-2%	9.2E-06	4.7E-06	-4.5E-06	-49%	2.30E-01
V-pol Feed +Y-Z	1.9E-01	-1.2E-03	8.8E-02	8.9E-02	-7400%	3.9E-02	3.79E-02	-1.4E-03	-4%	3.0E-02	1.5E-02	-1.5E-02	-51%	5.4E-05	2.0E-05	-3.4E-05	-64%	2.30E-01
V-pol Feed -Y+Z	4.0E-02	2.5E-02	1.5E-01	1.2E-01	488%	3.3E-01	3.29E-01	2.0E-04	0%	2.0E-01	2.0E-01	1.6E-03	1%	1.5E-05	8.0E-06	-7.4E-06	-48%	2.30E-01
H-pol Feed Bipod +Y+Z	1.5E-01	-9.3E-03	3.4E-02	4.4E-02	-469%	1.6E-02	1.39E-02	-1.6E-03	-10%	1.3E-02	5.6E-03	-7.4E-03	-57%	1.6E-04	1.0E-03	8.4E-04	512%	4.56E+00
H-pol Feed Bipod -Y-Z	2.4E-02	1.9E-02	7.1E-02	5.2E-02	275%	1.6E-01	1.59E-01	-2.0E-04	0%	8.0E-02	6.5E-02	-1.5E-02	-18%	8.5E-05	2.4E-03	2.3E-03	2737%	4.56E+00
V-pol Feed Bipod +Y-Z	8.6E-02	-9.9E-03	3.7E-02	4.7E-02	-478%	1.6E-02	1.61E-02	-1.0E-04	-1%	1.3E-02	6.5E-03	-6.3E-03	-49%	1.1E-04	1.6E-03	1.5E-03	1343%	4.56E+00
V-pol Feed Bipod -Y+Z	4.7E-02	1.9E-02	8.7E-02	6.9E-02	372%	1.7E-01	1.70E-01	1.0E-04	0%	8.7E-02	7.1E-02	-1.6E-02	-18%	1.5E-04	5.4E-05	-1.0E-04	-65%	4.56E+00
Metering Structure	2.5E-02	2.6E-03	1.3E-02	1.1E-02	408%	1.2E-02	1.24E-02	6.0E-04	5%	2.8E-03	4.9E-03	2.1E-03	75%	1.6E-04	1.1E-03	9.4E-04	607%	1.14E+00
+Y Boom Inboard	8.3E-02	7.5E-02	6.9E-02	-5.3E-03	-7%	3.8E-02	3.61E-02	-2.2E-03	-6%	2.4E-02	3.4E-02	9.5E-03	39%	9.9E-04	1.0E-03	8.7E-06	1%	4.90E-01
+Y Boom Outboard	7.4E-02	2.1E-02	7.2E-02	5.1E-02	242%	5.7E-02	3.61E-02	-2.1E-02	-36%	2.8E-02	4.2E-02	1.4E-02	48%	2.2E-03	2.2E-03	0.0E+00	0%	4.90E-01
-Y Boom Inboard	8.5E-02	1.6E-03	9.4E-02	9.2E-02	5763%	7.0E-02	6.98E-02	-5.0E-04	-1%	2.7E-02	3.5E-02	7.4E-03	27%	3.7E-04	4.2E-04	4.7E-05	13%	4.90E-01
-Y Boom Outboard	7.4E-02	-8.1E-03	7.0E-02	7.9E-02	-969%	3.7E-02	3.67E-02	-2.0E-04	-1%	1.8E-02	2.4E-02	5.5E-03	30%	1.1E-03	1.4E-03	3.0E-04	27%	4.90E-01
IRA Truss +Y+X	3.8E-01	3.6E-01	6.2E-01	2.6E-01	70%	1.2E+00	9.99E-01	-1.7E-01	-15%	1.5E+00	1.0E+00	-4.4E-01	-30%	7.5E-05	6.1E-05	-1.4E-05	-19%	1.82E+00
IRA Truss +Y-X	3.8E-01	3.2E-01	5.9E-01	2.7E-01	84%	1.4E+00	1.15E+00	-2.1E-01	-16%	1.5E+00	1.1E+00	-4.8E-01	-31%	7.5E-05	5.9E-05	-1.6E-05	-21%	1.82E+00
IRA Truss -Y+X	3.9E-01	-1.8E-01	3.8E-01	5.7E-01	-308%	2.9E-01	2.89E-01	2.3E-03	1%	1.1E-01	9.0E-02	-1.9E-02	-17%	7.8E-05	4.4E-05	-3.5E-05	-44%	1.82E+00
IRA Truss -Y-X	3.8E-01	-1.9E-01	3.8E-01	5.8E-01	-301%	2.9E-01	2.94E-01	2.1E-03	1%	1.1E-01	9.4E-02	-1.6E-02	-15%	4.4E-05	1.4E-05	-3.1E-05	-69%	1.82E+00
Reflector Panels All	2.2E+00	2.5E+00	2.4E+00	6.4E-02	3%	2.7E+00	2.37E+00	-3.3E-01	-12%	1.2E+00	7.4E-01	-4.5E-01	-38%	1.1E-04	1.2E-04	1.1E-05	10%	6.11E+00

No new violations.

Some components have large % change but absolute stabilities are still within requirements with margins



# Conclusion

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**Solar array position with respect to beta angle has small impact to temperature stability**

- All analysis showed components within stability requirement except –Y Feeds for 31.6 min duration
- No new violation

**STOP Analysis Plan:**

- Continue to use 0° S/A position to minimize errors that might be introduced in rotating solar array
  - Rotating solar array is a manual process that can introduce errors
  - 0° S/A results in less stable performance at higher Beta angles than the actual flight position (conservative)



## **5.3.1.6**

# **Variable Earth IR Sensitivity**



48th International Conference on Environmental Systems  
July 2018, Albuquerque, NM

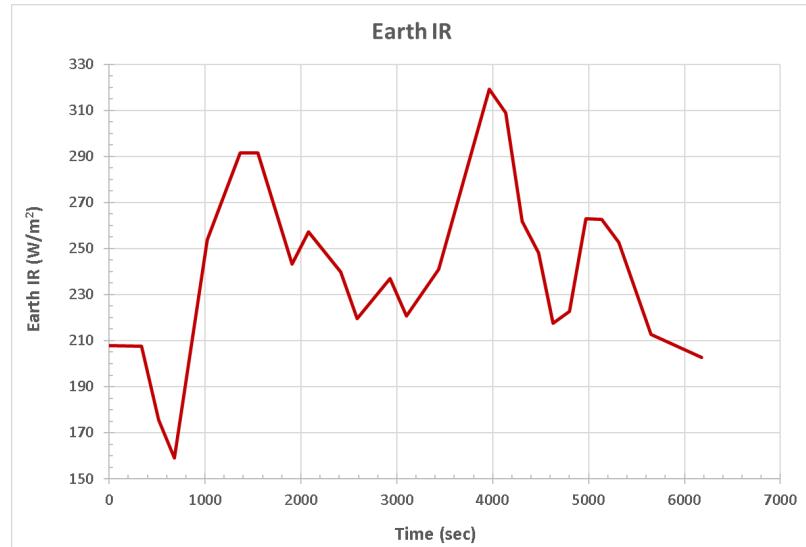
# Assumptions

## Objective:

- Study the effects of variable Earth IR on temperature stability

## Run Information:

- Deployed model used for WHC with  $\beta = 55^\circ$
- Case #1: constant EIR = 265W/m<sup>2</sup>
- Case #2: variable EIR
  - Variable Earth IR profile for planet
  - Data from ERBS
  - Largest Earth IR change = 130 W/m<sup>2</sup> over 500 secs



# Summary – Variable EIR

	Constant Albedo	Variable EIR	Delta	Delta, %	REQ	Constant Albedo	Variable EIR	Delta	Delta, %	REQ
	Max 1- $\sigma$	Max 1- $\sigma$				Max 1- $\sigma$	Max 1- $\sigma$			
	2.6min	2.6min				31.6min	31.6min			
H-pol Feed +Y+Z	8.9E-04	8.8E-04	-1.8E-06	0%	3.00E-02	3.7E-02	5.4E-02	1.8E-02	48%	2.30E-01
H-pol Feed -Y-Z	2.1E-02	1.9E-02	-2.2E-03	-11%	3.00E-02	3.6E-01	4.4E-01	7.9E-02	22%	2.30E-01
V-pol Feed +Y-Z	7.0E-04	7.3E-04	3.0E-05	4%	3.00E-02	3.9E-02	5.6E-02	1.7E-02	43%	2.30E-01
V-pol Feed -Y+Z	1.5E-02	1.6E-02	1.2E-03	8%	3.00E-02	3.3E-01	3.4E-01	1.2E-02	4%	2.30E-01
H-pol Feed Bipod +Y+Z	1.5E-04	8.8E-04	7.3E-04	473%	5.4E-01	1.6E-02	2.1E-02	5.0E-03	32%	4.56E+00
H-pol Feed Bipod -Y-Z	1.9E-03	1.9E-02	1.7E-02	884%	5.4E-01	1.6E-01	1.9E-01	2.8E-02	18%	4.56E+00
V-pol Feed Bipod +Y-Z	1.3E-04	7.3E-04	6.0E-04	450%	5.4E-01	1.6E-02	2.0E-02	4.2E-03	26%	4.56E+00
V-pol Feed Bipod -Y+Z	1.9E-03	1.6E-02	1.4E-02	732%	5.4E-01	1.7E-01	1.8E-01	9.5E-03	6%	4.56E+00
Metering Structure	1.9E-04	1.6E-04	-2.8E-05	-15%	1.30E-01	1.2E-02	1.7E-02	4.9E-03	42%	5.00E-01
+Y Boom Inboard	1.9E-04	2.1E-04	2.0E-05	10%	6.00E-02	3.8E-02	4.4E-02	5.5E-03	14%	4.90E-01
+Y Boom Outboard	8.6E-04	7.8E-04	-7.7E-05	-9%	6.00E-02	5.7E-02	6.7E-02	9.9E-03	17%	4.90E-01
-Y Boom Inboard	1.1E-03	1.0E-03	-1.0E-04	-9%	6.00E-02	7.0E-02	9.1E-02	2.1E-02	30%	4.90E-01
-Y Boom Outboard	5.9E-04	5.2E-04	-7.3E-05	-12%	6.00E-02	3.7E-02	5.5E-02	1.8E-02	50%	4.80E-01
IRA Truss +Y+X	6.6E-03	7.0E-03	4.0E-04	6%	2.20E-01	1.2E+00	1.2E+00	6.7E-03	1%	1.80E+00
IRA Truss +Y-X	6.6E-03	6.8E-03	2.0E-04	3%	2.20E-01	1.4E+00	1.4E+00	5.1E-02	4%	1.80E+00
IRA Truss -Y+X	4.3E-03	3.6E-03	-7.0E-04	-16%	2.20E-01	2.9E-01	3.8E-01	8.9E-02	31%	1.80E+00
IRA Truss -Y-X	4.3E-03	3.6E-03	-7.0E-04	-16%	2.20E-01	2.9E-01	4.0E-01	1.1E-01	37%	1.80E+00
Reflector Panels All	7.0E-02	6.5E-02	-5.8E-03	-8%	7.30E-01	2.7E+00	3.3E+00	6.0E-01	22%	6.10E+00

Some components have large % change for 2.6 min duration but absolute stabilities are still within requirements with healthy margin.

# Conclusion

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## Results

- In general, all stability margins for 31.6 min duration are decreased with variable EIR. However, there is no new violation
- Relative changes in stabilities with 2.6min duration are very large for Feed Bipod but they meet the requirement with healthy margin

## STOP Analysis Plan

- Continue using constant Earth IR (16hrs) due to significant increase in analysis time for variable Earth IR case (65hrs)

